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The Welfare Consequences of Green Tax Reform in Small Open Economies

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*Selected Paper prepared for presentation at the American Agricultural Economics Association
Annual Meeting, Providence, Rhode Island, July 24-27, 2005*

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Abstract

This research explores the welfare consequences of substituting carbon taxes for conventional distortionary taxes in a small open economy, using Pennsylvania as case study. A computable general equilibrium (CGE) model is developed for Pennsylvania to simulate possible outcomes when carbon taxes are substituted for conventional taxes.

Consumer welfare impacts from environmental tax reform are conventionally decomposed into three effects: the Pigouvian effect, the tax revenue recycling effect, and the tax interaction effects. The Pigouvian effect is a welfare gain from reducing environmental externalities. The tax revenue effect is a welfare gain from reduced distortion in factor and commodity markets that results from the substitution of the environmental tax for conventional distortionary taxes. The tax interaction effect is a welfare loss due to increased distortion of factor and commodity markets induced by environmental taxes, given that distortionary taxes are not eliminated. The 'Double dividend' hypothesis argues that the sum of welfare gains is larger than the welfare loss. Most research on this debate has been done using closed-economy models.

Small open economies, however, have different aspects from closed economies. These include endogenous factor mobility and trade. Factor mobility triggered by changes in real wages and environmental quality can affect distortions of regional labor market, leading to the different welfare outcomes.. When the carbon tax is imposed in open economies, inter-regional trade sectors are more responsive than foreign trades, since the elasticity of substitution for inter-regional trades is higher than that for the foreign trades. This different inter-regional trading effect leads to different welfare outcomes.

Introduction

Since 1990s, US states have shown growing interest in substituting environmental taxes for conventional taxes. However, most economic research on the environmental taxes has been done within the context of closed economies. This research explores welfare consequences of replacing conventional taxes with carbon taxes in a small open economy, using possible tax reforms in Pennsylvania as a case study.

One environmental tax receiving much attention is a tax on carbon. Pennsylvania ranked fourth among the states in U.S. GHG emissions in 1998 (Science Daily, 2003). The state is an observer in the Regional Greenhouse Gas Initiative (RGGI), which is consortium of state governments exploring the reduction of GHGs in the northeast states. (www.RGGI.org) The major goals of the study are to examine the welfare implications for consumer, and price and quantity changes of energy production goods as carbon taxes are imposed by the state.

The literature on the welfare consequences from environmental taxes in closed economies has identified three types of effects that determine the welfare of consumers: (1) the environmental effect (or Pigouvian effect), which is the economic gain with a reduction in environmental externalities; (2) the tax revenue recycling effect, which is the economic gain from substituting environmental tax revenues for revenues from conventional distortionary taxes; and (3) tax interaction effects, which are efficiency losses that result when environmental taxes induce market responses that enlarge remaining tax distortions.

A key issue in the literature is whether the revenue recycling effect is offset by the negative interaction effect. This issue has been the focus of the literature on the 'double dividend' hypothesis (e.g. Lee and Misiolek, 1986; Pearce, 1991; Repetto et al, 1992; Oates, 1993; Poterba, 1993). Research on the environmental taxes has focused on the national level tax policy and welfare outcomes, with theoretical and empirical research largely based on closed economy general equilibrium models. However, state economies are better viewed as "small open

economies,” attributes of which can affect the size and nature of the welfare effects.

The major state-specific features are factor mobility and inter-regional trade. Migration research suggests that real wage differential or environmental differential can determine the inter-regional migration patterns (Goetz, 1999; Deller et al, 2001; Garber-Yonts, 2004). For instance, as labor income taxes are reduced due to the revenue recycling of carbon taxes, the real wage rate increases, which results in the net in-migration of labor. On the other hand, when carbon taxes are substituted for distortionary taxes, the overall environmental amenities in the focus region will be improved. This leads may lead to an increased inflow of labor in the focus region. When labor mobility is considered, the wage elasticity of labor supply will be higher than that in the labor market without labor mobility. This difference affects the size of the deadweight loss (excess burden) of labor income taxes.

Inter-regional trade is more important to state economies than foreign trade, since most trading occurs among different states. The elasticity of substitution between regional products and import goods or the elasticity of transformation between the regional demand and export demand is generally higher than the elasticities between regional goods and foreign traded goods. Therefore, changes in the prices and taxes in the focus region influence inter-regional trade more significantly than foreign trade.

Numerical results on the consumer’s welfare consequences and major endogenous variables including factor demand and supply, commodity demand and supply, export and import demand are derived using a static regional computable general equilibrium (CGE) model that captures specific features of state open economies, most notably endogenous factor mobility and price and quantity changes in a two-tier trade system. We explore substituting carbon taxes for household income taxes or social security taxes in Pennsylvania using a static CGE model. We consider scenarios in which Pennsylvania acts unilaterally, and scenarios in which carbon taxes are imposed elsewhere.

Pennsylvania CGE Model

The Pennsylvania CGE model consists of seven industries (energy production, transportation, and other materials), one representative household, three value added inputs (labor, proprietary, and capital services), federal and state/local governments, enterprise, saving-investment, foreign and inter-regional trade. There are seven sectors for the production and consumption of goods: coal, petroleum, natural gas, alternative fuels, electricity, transportation, and all the other materials. Governments are composed of federal, state/local-non education government, and state/local-education to look at the different effects on the revenue and expenditure among federal, state and local government with/without education section. Taxes consist of indirect business tax, household income tax, social security tax, proprietary tax, corporate profit tax, and export taxes. Energy production sectors consist of coal, petroleum, natural gas, alternative fuels, and electricity. GHGs gases are generated from the consumption of fossil fuels such as coal, petroleum, and natural gas. Production sectors have a nested CES (constant elasticity of substitution) function system to capture the interaction among different fuel sectors, value-added inputs, and other materials.

Carbon taxes are imposed on the use of fossil fuels by production as well as final consumption¹.

The basic data employed in the Pennsylvania CGE model are hybrid social accounting matrix. Production and utility systems consist of nested CES (constant elasticity of substitution) functions. Environmental amenities are a diminishing function of energy consumption. Trade system has two-tier Armington and CET (constant elasticity of transformation) functions. Labor mobility is endogenized as a function of relative real wage rate and environmental quality, and the mobility of other factors are not considered for simplicity.

¹ Households consume fossil fuels for heat, electricity, and driving.

1. Hybrid social accounting matrix

All flows of payments or transfers among the entities of institutions are based on a Social Accounting Matrix (SAM) of Pennsylvania economy in 2000 and energy consumption data from EIA (Energy Information Administration). A regional SAM provides a comprehensive snapshot of the economy during a given year (Decaluwe, et al, 1999). The Pennsylvania SAM was derived from IMPLAN (Impact Analysis for PLANning) for the year 2000 (IMPLAN Pro, 2000). The integrated SAM has two different units: value (dollars) and energy quantities (BTUs). The input-output transactions included in this transformed SAM are referred to as 'hybrid commodity by commodity input-output table' (Miller and Blair, 1985; Brenkert et al, 2004). Prices of energy production sectors are derived from dividing the total output values by quantities, and the quantity terms are changed into value terms by multiplying the quantities by the prices.

The institutions of the Pennsylvania economy are divided into representative household, industries, federal and state/local government, and rest of world (ROW) and rest of USA (ROUS). There are seven sectors for the production and consumption of goods: coal, petroleum, natural gas, alternative fuels, electricity, transportation, and all the other materials. Energy production sectors consist of coal, petroleum, natural gas, alternative fuels, and electricity. GHGs gases are generated from the consumption of fossil fuels such as coal, petroleum, and natural gas. Carbon taxes will be imposed on the use of fossil fuels by production as well as final consumption².

Table 1 shows consumption of fossil fuels, alternative fuels, and primary electricity by sectors and households in the year 2000.

[Insert table 1 about here]

² Households consume fossil fuels for heat, electricity, and driving.

2. Production and utility

Figure 1 shows the overall production system. Combined value added inputs (VA) consist of labor (L), proprietor's service (F), capital (K), and energy (E). Labor and proprietary services are combined in a second CES function, while capital and energy are bundled in the other second level-CES function. Energy is composed of electricity, gas, oil, coal, and alternative fuels such as solar, hydroelectricity, nuclear electricity and others in a third CES. Electricity is a function of coal, oil, gas, input electricity (nuclear and hydroelectricity), and other fuels (ALTF) such as hydroelectricity, nuclear electricity, and others in the CES function (Figure 1).

[Insert figure 1 about here]

In the second CES function, a composite intermediate input is divided into transportation and all other materials. Transportation is a function of oil, gas, electricity and alternative fuels in the CES function (Figure 2).

[Insert figure 2 about here]

Utility functions have the following nested system in figure 3. The first tier utility function consists of demand for leisure (R) and aggregated market goods (\bar{c}). In the second tier, the aggregated market good (\bar{c}) is divided into seven market commodities. The market goods consist of CES functions. Market goods are produced by industries which employ value-added inputs and intermediate inputs.

3. Environmental damage function

Pigouvian (environmental) effects accrue as the consumption of energy-intensive goods is diminished due to the imposition of carbon taxes. To evaluate the Pigouvian effect on migration, environmental amenities should ideally enter the household utility function as a non-separable variable (Schwartz and Repetto, 2000; Williams III, 2002 and 2003). In this study, an alternative approach is employed to capture the Pigouvian effect on migration. Following Böhringer et al (2003) an environmental damage function is specified. The damage function is

$$AMEN = \overline{ENV} - \frac{\pi}{2} \times TCE^2$$

Where AMEN is the condition of environmental amenity, \overline{ENV} is the endowment of environmental amenity in Pennsylvania, π is emission coefficient, and TCE is total consumption of energy goods such as coal, gas, oil, and electricity.

4. Trade system

Trade is divided into foreign trade and inter-regional trade. The former is related with foreign export and import between the rest of the country (ROW) and Pennsylvania, while the latter involves domestic export and import between other U.S. states (ROUS) and Pennsylvania. Armington and CET (Constant Elasticity of Transformation) functions are used to for allocation of traded and non-traded goods given that cross hauling is assumed.

Regional output (X) is allocated between domestic output supply (SD) and foreign export (FE). Domestic output supply is allocated between regional supply (XXS) and domestic export (DE). Total regional absorption (Q) is defined as regional output (X) plus public good provision (GS) plus foreign import (FM) and domestic import (DM) minus foreign export (FE) minus domestic export (DE). The private regional absorption (Q – GS) is decomposed

into domestic demand (XD) and foreign import demand (FM). Domestic demand (XD) is divided into regional demand (XXD) and domestic import (DM).

Finally, regional supply (XXS) is equal to regional demand (XXD) by the above trade structure. We assume the export and import price in ROW and ROUS level are equal to one and do not deal with tariff because this is a state economy. Figure 4 shows the structure of trading sectors.

[Insert figure 4 about here]

5. Labor mobility

Literature review on labor migration and environmental amenities supports that labor will move into the focus region as net real wage rates and value of environmental amenities in the focus region increase (Goetz, 1999; Deller et al, 2001; Garber-Yonts, 2004). Net real wage rates reflect labor income taxes and prices of commodities. As labor income taxes are reduced due to the carbon tax reform policy, real wages are increased, so labor flows into Pennsylvania. On the other hand, as the price of market commodities goes up as a result of imposing carbon taxes, real wages are diminished, thus workers move out of Pennsylvania. Changes in relative environmental amenities affect the decision of labor migration. The improved environmental quality in Pennsylvania resulting from carbon taxation attracts migrants to move into the region.

$$L_{mig} = \varepsilon_1 \log(w_{PA} / w_{RUS}) + \varepsilon_2 \log(AMEN_{PA} / AMEN_{RUS})$$

Labor migration (L_{mig}) is a function of natural log of relative net real wage and natural amenities. ε_1 and ε_2 implies wage elasticity of migration and amenity elasticity of migration.

Labor migration affects the total amount of regional labor supply (GLS). The total labor supply is sum of labor migration and net regional labor supply (LS).

Scenarios and results

Carbon taxes are imposed on the use of fossil fuels such as coal, petroleum, and natural gas to maintain 1990 emissions level. The main consumption sectors are electricity and transportation. Households consume the fossil fuels for heating, cooling, and transportation as well. Thus, the base for carbon taxes includes household and industrial sectors

The basic scenarios consist of i) no factor mobility, ii) factor mobility without environmental damage function, and iii) factor mobility with the environmental damage function. The three cases are combined with a) state carbon taxes b) national carbon taxes. There are six cases with the combination of scenarios (Table 2).

[Insert table 2 about here]

To calculate the tax revenue recycling and tax interaction welfare effects, compensating and equivalent variation measures are used. applied. Pigouvian effect (D_p) is derived using the relative changes in environmental amenities (Q_e), initial income of household (INC_h) and household utility (U_o) (Böhringer et al, 2003).

$$D_p = \frac{Q_e^1 - Q_e^0}{Q_e^0} INC_h \frac{Q_e^0}{U_o}$$

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Appendix: Tables and Figures

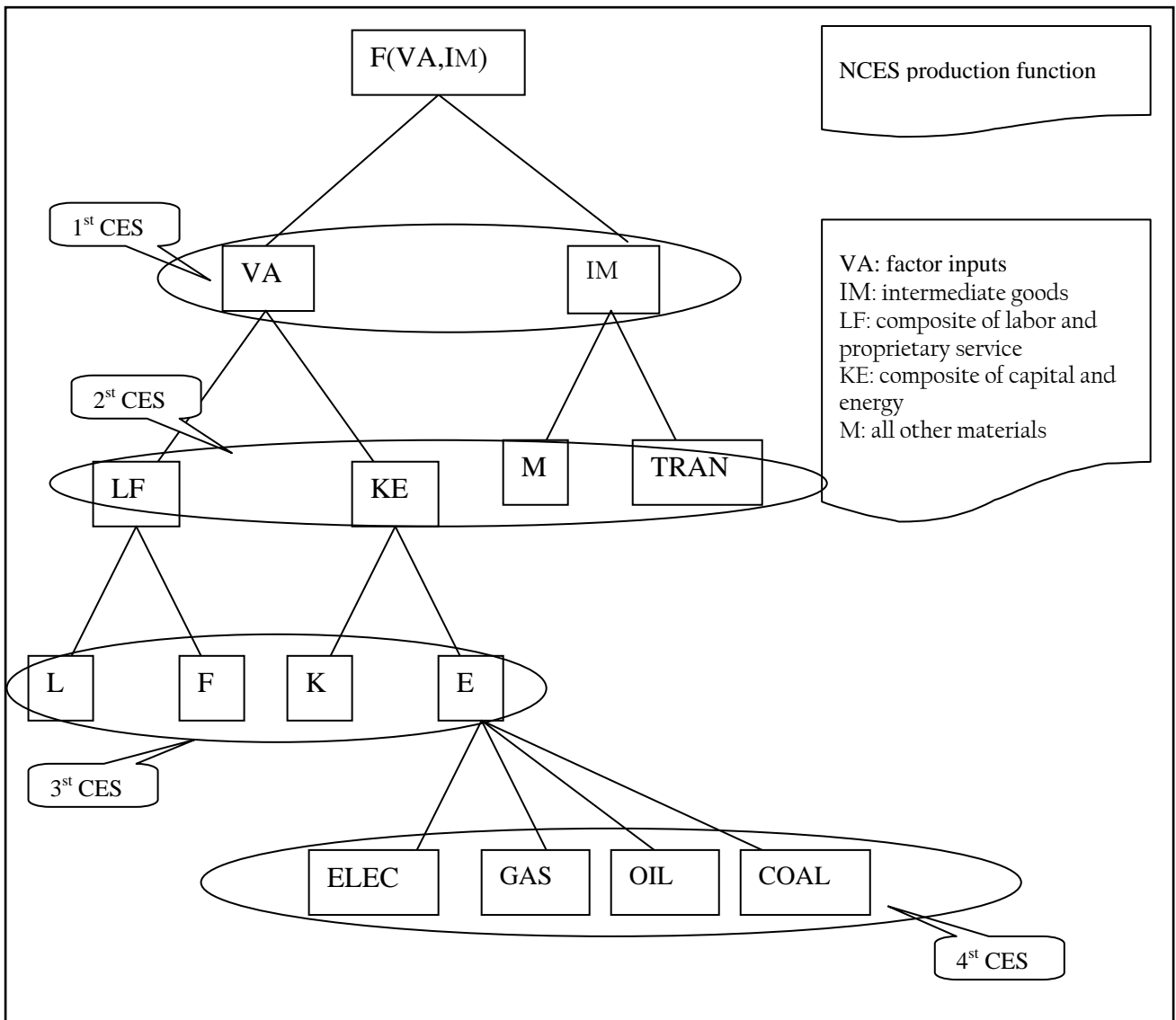
Table 1. Energy consumption by sectors

	<i>Electricity</i>	<i>Transport</i>	<i>Materials</i>	<i>Final demand</i>
Coal	1210.6	0	295.3	2.2
Gas	21.3	40.2	394	272
Petroleum	45.1	955.2	279.3	153.8
Alternative fuels	31.6	1.1	54.1	14.8
Electricity	788.6	1.4	301.8	153.6

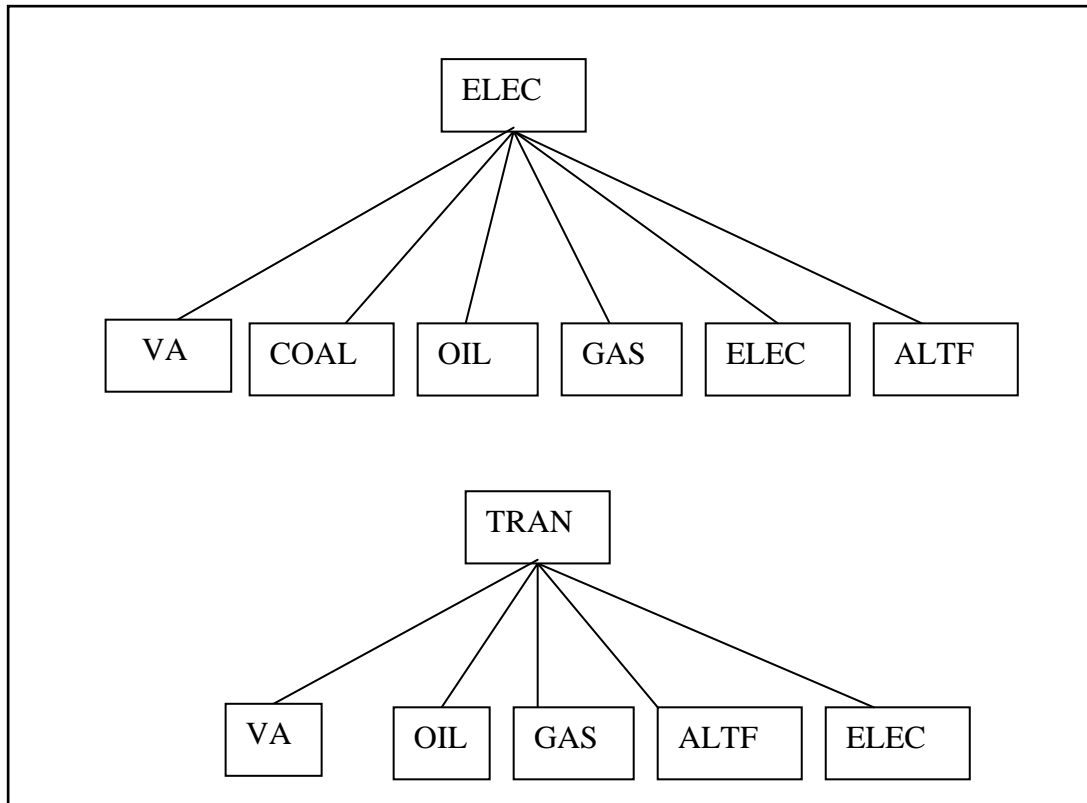
(Recalculated from EIA, State Energy Data 2001: Consumption)

Table 2. The combination of scenarios for CGE model simulation

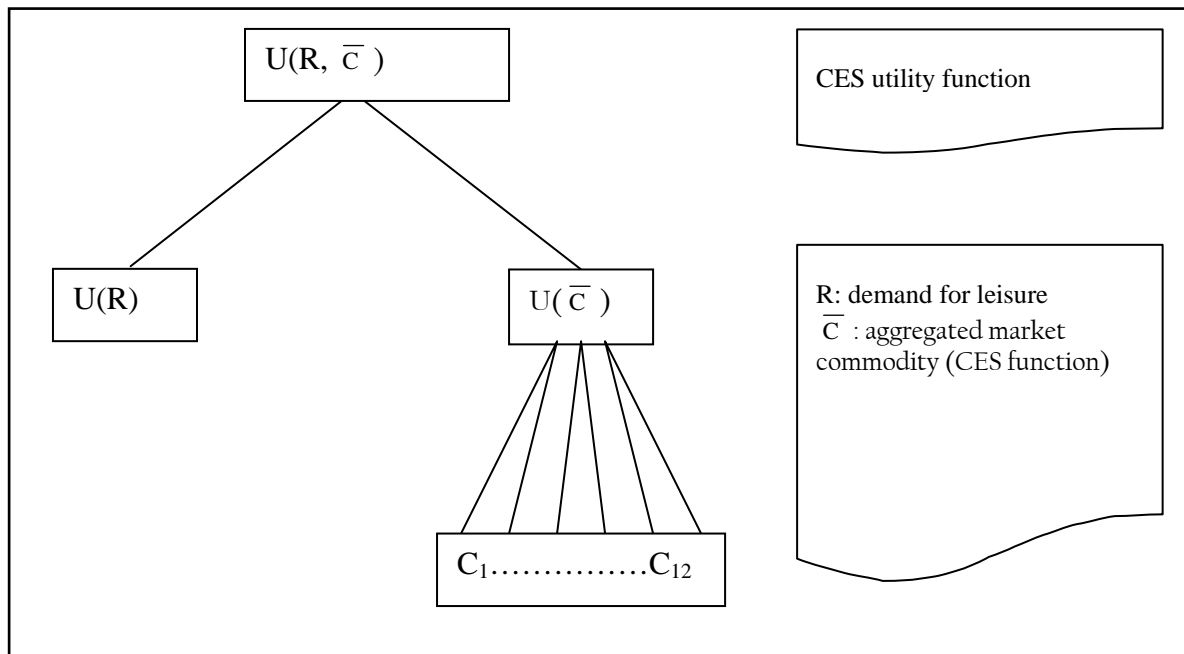
Scenarios	i) No factor mobility	ii) Factor mobility without environmental damage function	iii) Factor mobility with the environmental damage function
a) State-wide carbon taxes	I	II	III
b) National carbon taxes	IV	V	VI



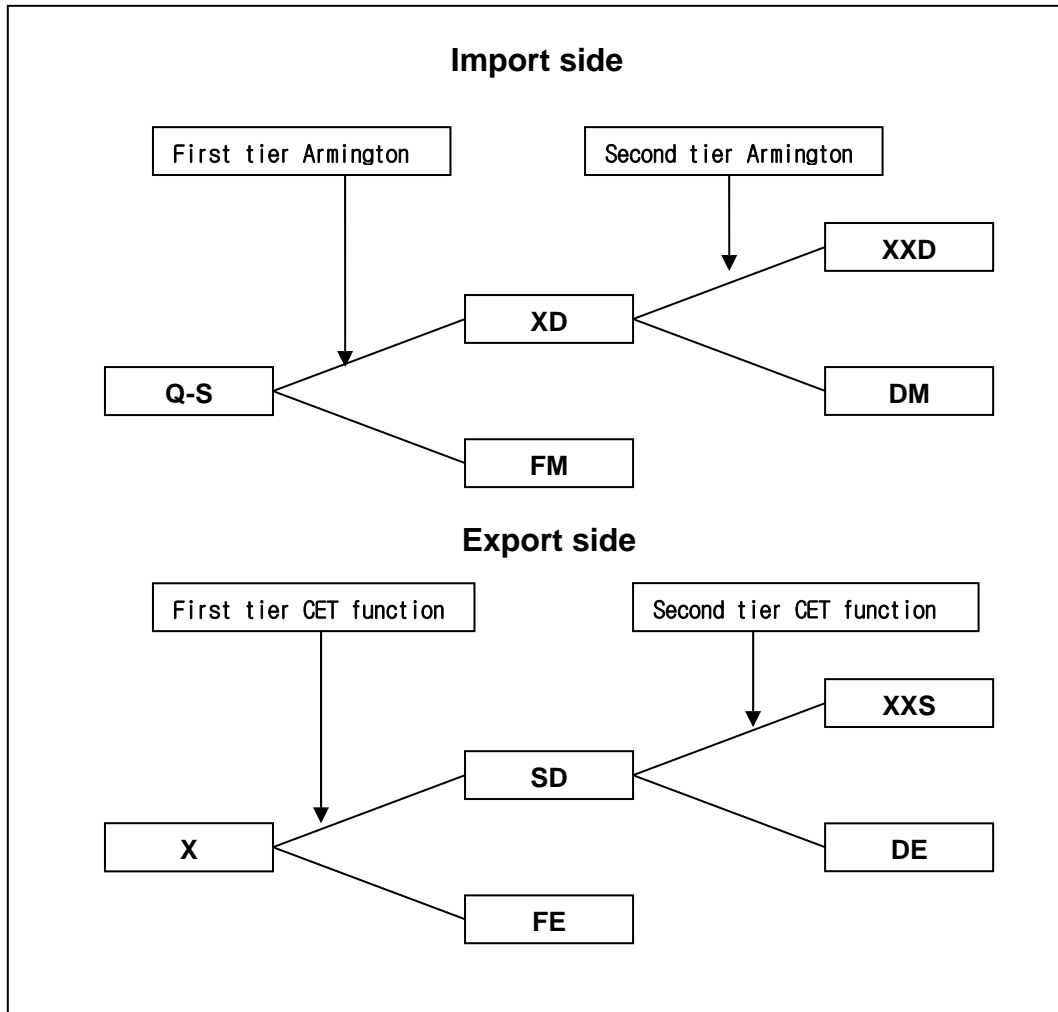
(Figure 1. NCES production system)



(Figure 2. production structure of electricity and transportation)



(Figure 3. Consumer's utility system with two-tier CES function)



(Figure 4. The structure of two-tier trading in Pennsylvania)